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DEVELOPMENT OF OBJECTIVE MAXIMUM/MINIMUM TEMPERATURE FORECAST EQUATIONS FOR ALASKA

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1. INTRODUCTION

Since August 1973, the Techniques Development Laboratory has produced objective calendar day maximum/minimum temperature (max/min) forecasts for over 200 stations in the conterminous United States (Klein and Hammons, 1975). The Model Output Statistics (MOS) approach (Glahn and Lowry, 1972) was used to develop the forecast regression equations. Hanas (1975) derived a similar set of MOS equations to predict the calendar day max and min for 14 stations (Table 1) in Alaska. From 0000 GMT model data, forecasts were available for today's max, tomorrow's min and max, and the day after tomorrow's min. This guidance was valid approximately 24, 36, 48, and 60 hours, respectively, after 0000 GMT. An analogous scheme for the 1200 GMT cycle generated forecasts for tomorrow's min and max, and the day after tomorrow's min and max. These were valid around 24, 36, 48, and 60 hours, respectively, after 1200 GMT. The Alaskan forecast equations were derived from developmental data stratified into two 6-month seasons: cool (October-March) and warm (April-September).

Hammons et al. (1976) later derived max/min temperature forecast equations for the conterminous 48 states that were based on a 3-month seasonal stratification of the developmental data: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). Verification results (Dallavalle et al., 1977) showed that the 3-month season equations were superior to the older 6-month equations. In fact, when precipitation probability and wind forecast equations were developed for Alaska (National Weather Service, 1979), 3-month seasons were used in the development. Until 1979, however, the Alaskan temperature forecasts were still produced from the original 6-month season equations.

In this paper, we describe the development of new 3-month max/min temperature forecast equations for Alaska. For the first time, an equation was included to predict the max for the day after tomorrow (approximately a 72-h forecast) from 0000 GMT model data. Prior to the final derivation of the equations, we tested on independent data to compare forecasts made from 3-month winter and 6-month cool season equations when available. We also experimented with two sets of predictors at the 60-h projection. Finally, we compared the MOS forecasts with those based on persistence, on equations derived solely from climatic terms, and on equations involving a combination of persistence and climatic factors.

2. PROCEDURE

In the MOS technique, a particular surface weather variable (predictand) observed at a station is correlated with output from meteorological numerical models, climatic terms, and surface weather observations (all termed "predictors"). For deriving temperature forecast equations, the model fields were interpolated from grid points via a biquadratic interpolation scheme to the station of interest. We then employed a forward, stepwise screening regression technique to derive a linear forecast equation. Predictors were chosen on the basis of contributing the most reduction of variance when combined with other predictors already selected. The predictand was the local calendar day maximum or minimum. Equations were derived for each station, each projection, and each cycle. The screening regression was stopped as soon as 10-term equations were developed or as soon as no additional predictor contributed more than 0.1% to the reduction in variance. The complete single-station equation has the following form:

$$\hat{Y}=a_0 + a_1X_1 + a_2X_2 + \dots + a_{10}X_{10} ,$$

where $\hat{Y}$ is the forecast temperature (max or min), a_0 is the regression constant, the a_i's ($i=1,2,\dots,10$) are the regression coefficients, and the X_i's are the predictors. In the Alaskan work, most equations used 10 terms, but there were some with nine or fewer.

The Techniques Development Laboratory has archived forecast fields from the primitive equation coarse mesh (PE) model (Shuman and Hovermale, 1968) since October 1969. This was originally a 6-layer model (6LPE), but since January 1978 a 7-layer PE (7LPE) model (National Weather Service, 1977) has been in use. With forecasts from both models combined, there were almost 10 years of data. However, we decided to eliminate the first 3 years, primarily because fewer forecast fields were archived during that time. Thus, our dependent sample consisted of nearly 6 years of model output from December 1972 through August 1978. We divided the year into four 3-month seasons: spring (March-May), summer (June-August), fall (September-November), and winter (December-February). In this report, we discuss development and testing of the winter season equations, and development of the spring, summer, and fall season equations.

Tables 2, 3, and 4 list the predictors used in the derivation of the 0000 GMT winter forecast equations. The PE model fields included forecasts of constant pressure level heights, temperatures, winds, vertical velocities, relative humidities, and other dynamic and thermodynamic quantities. In general, model output was valid around the projection time of the forecast max or min. Fields involving humidity, vertical velocity, boundary layer terms, or computed quantities (e.g., wind divergence and relative vorticity) were usually smoothed in the earlier projections by a five-point filter in order to reduce model "noise." The same fields were smoothed by a nine-point filter as the forecast projection increased. In addition, most model fields were smoothed by a five- or nine-point filter before development of the 60- and 72-h forecast equations.

In Table 3, we listed two sets of predictors for the equations to predict the day after tomorrow's min from 0000 GMT data. One list ("extnd") was actually used in the final development of the 0000 GMT equations. We originally included some 72-h forecast fields in this first group, but operational constraints forced us to eliminate those quantities. The second set ("altrn") was tested as an alternate group of predictors for the 0000 GMT cycle. This same set was used as predictors for the 60-h max in the 1200 GMT derivation.

Observations (Table 4) were included in the development of equations for the first two projections (approximately a 24-h max and 36-h min from 0000 GMT). In particular, we screened the ceiling, sky cover, u and v components of the surface wind, wind speed, temperature, and dew point observed at the station at 0600 GMT. The ceiling was included as a binary predictor with a cutoff of 5000 feet. Thus, if the observed ceiling was less than or equal to 5000 feet, the predictor was set equal to one; otherwise, it equaled zero. For the forecast of today's max, we also used the observed previous day's max; for tomorrow's min, we screened the observed previous min. Since station observations are not always available in daily operations, we also developed equations for the first two projections that did not require any station observations. Finally, climatic terms (first two harmonics of the day of the year and the daily solar insolation at the top of the atmosphere) were included as potential predictors in all projections (Table 4).

A similar set of predictors (not shown) was used for the 1200 GMT equations. However, the model projections and the surface observations refer to hours after 1200 GMT. As noted earlier, the alternate group of 60-h predictors in Table 3 was used in the derivation. For the 1200 GMT cycle, no 72-h temperature forecast equations were developed.

3. TESTS

As a test of the new equations, we first derived 0000 GMT equations from 5 years of winter data (December 1972-February 1977) and made forecasts from these equations on an independent sample (December 1977-February 1978). We wanted to see whether observations in the forecast equations for the first two projections and the "extnd" predictor set for the 60-h forecasts improved the accuracy of the guidance. We also compared forecasts based on these 3-month winter equations with those produced by the older 6-month cool season equations. Additionally, we made persistence forecasts of the max or min for the 1977-78 winter. Finally, we developed, from the 1972-77 winter data, two other sets of regression equations: one based on the climatic terms (climatology) in Table 4 and another (persistence-climatology) based on a combination of persistence and climatic factors. This latter set was obtained by screening the climatic predictors and the previous day's max (min) to derive an equation to predict the max (min) at a given projection. The climatology and persistence-climatology equations were developed for all five projections from 0000 GMT. However, because the climatic terms vary slowly from one day to the next, the climatology equations for the three projections of the max were essentially identical for each station as were the two equations for the min forecasts. All of the equation sets were tested on the same 1977-78 winter data.

The average standard errors of estimate on the dependent sample for the 0000 GMT max/min equations based on 5 winter seasons (December 1972-February 1977) are given in Table 5. For the first projection, the use of observations as potential predictors decreased the average standard error of estimate by 1.0°F. This was the largest improvement yet seen from screening observations in MOS temperature development; Hammons et al. (1976) list comparable errors for the 48 conterminous states. For the second projection, the average standard error of the Alaskan equations was reduced by 0.4°F with the aid of station observations. This also was much larger than a corresponding improvement in the average error for the 48 contiguous states. The "extnd" predictor set improved the standard error of the 60-h min forecast equations by only 0.03°F compared to the alternate predictor set. From this table, it is evident that the min is particularly difficult to predict. The standard error for the min forecast equation sets, valid approximately 36 and 60 hours after 0000 GMT, exceeded the error for the max forecast equations valid approximately 12 hours later. We have noted previously (Hammons et al., op. cit.) that the min is highly variable and more difficult to predict in the winter because of the overriding influence of small-scale features such as drainage winds and low-level cloudiness--quantities that the synoptic-scale models often fail to resolve. Certainly, this characteristic is magnified in Alaska where the terrain is highly irregular and where sunlight is weak or absent during most of the winter.

In Table 5, we also included the average standard errors of estimate for the climatology and persistence-climatology forecast equations. The results indicate that neither equation set was competitive with the MOS equations for any of the projections.

The average mean absolute errors for the test forecasts (1977-78 winter) are plotted in Fig. 1 as a function of the projection. For the first four projections, the new 3-month equations were consistently better than the older 6-month equations. However, the margin of improvement in mean absolute error was only 0.1°F for the forecasts of today's max (including observations as predictors) and tomorrow's max (approximately a 24- and 48-h projection, respectively). In contrast, the improvement in mean absolute error for tomorrow's min and the day after tomorrow's min (approximately a 36-h and 60-h projection, respectively) was nearly 0.3°F and 0.5°F for the two projections. For both the 3- and 6-month equations, the use of observations as predictors in the first projection improved the mean absolute error by nearly 1.0°F. However, in this test, the 3-month equations that used observations to predict tomorrow's min were no more accurate on the average than the 3-month equations that did not contain station observations. Though it is not shown in Fig. 1, the extended range predictors for the 60-h projection improved the average forecast accuracy by 0.2°F over the 3-month equations that used no model predictors valid beyond 48 hours after 0000 GMT. It seems clear that there is forecast information available in the longer projections of the PE model.

It is quite evident from Fig. 1 that the forecasts based solely on climatic terms had very little skill compared to the MOS forecasts, even at the 72-h projection. The forecasts based on persistence alone were competitive at the first projection where their mean absolute error was identical to that produced by the 6-month equations using no observations. After the first period, however, the persistence forecasts were much less accurate than the MOS guidance. The persistence-climatology prognoses were better overall than persistence or climatology alone, but were not competitive with the MOS guidance.

4. DEVELOPMENT OF WINTER EQUATIONS FROM 6 SEASONS OF DATA

After our tests were completed, we rederived the winter max/min forecast equations from all 6 seasons of data (December 1972-March 1978); this included approximately 500 days. For the 60-h projection from 0000 GMT, we used the extended predictor list (Table 3); for the same projection from 1200 GMT, we employed the alternate list. The standard errors of estimate for both cycles combined are given in Fig. 2. Note that the min is substantially more difficult to forecast than the max. As before, the use of observations in the first projection improved the standard error by more than 1.0°F, while in the second projection the improvement declined to approximately 0.5°F. It is also noteworthy that the standard errors for the rederived 0000 GMT equations were within 0.06°F of the error for the corresponding test equations. Of the 154 operational forecast equations needed for all projections, all stations, and both cycles, only seven equations had less than 10 terms.

The five most important predictors for each projection are given in Tables 6 and 7 for the 0000 GMT and 1200 GMT winter season equation sets, respectively. This ranking was determined both by the frequency of selection and the order in which the predictor was chosen for the equation. The same basic predictors are generally important in all projections and both cycles. Usually, some indication of the low-level temperature (namely, the boundary layer potential temperature, the 850-1000 mb thickness, or the 850-mb temperature) is combined with a measure of the moisture field, like the boundary layer relative humidity or the precipitable water, to provide the most significant predictors. The boundary layer wind speed also is frequently selected. When surface observations are included as possible predictors in the first projection, the previous day's max, or the current day's min, is important for forecasting today's max or tomorrow's min, respectively. In short, persistence is useful as a way of indicating the overall temperature pattern. For the second projection, the observed surface temperature also is an important predictor.

The equation for today's max during the winter season at Fairbanks is shown in Table 8. There are two surface observations as predictors, namely, the 0600 GMT temperature and the previous day's maximum. Boundary layer quantities, such as the relative humidity, potential temperature, and wind speed, are also used. Note that even in this first projection equation the daily insolation, which is a climatic term, was picked as the third predictor. In operations, if the necessary surface observations at Fairbanks are missing, then a backup equation (not shown) requiring only model fields and climatic terms is used to produce the guidance. Similar sets of regression equations exist for all 14 stations.

5. DEVELOPMENT OF SPRING EQUATIONS

After the development of the winter equations, we proceeded to derive spring season (March-May) maximum/minimum temperature forecast equations for Alaska. There were 6 seasons (March 1973-May 1978) of data (approximately 500 days). The procedure used and the predictors screened were identical to the derivation for the winter season. The standard errors of estimate for the spring max/min equation sets are given in Fig. 3. The general trends are quite similar to those indicated for the winter equations (Fig. 2). As in the winter, the min is more difficult to forecast during the spring. Note that the use of observations in the first and second projection spring season equations decreased the standard errors by roughly 0.6°F and 0.3°F, respectively. This was less than the improvement observed in the winter season, but it followed trends that we have noticed previously (Hammons et al., 1976).

The five most important predictors for the 0000 GMT and 1200 GMT Alaskan spring season max/min forecast equations are given in Tables 9 and 10, respectively. Generally, the same fields that were important in the winter were also important in the spring. The 850-mb temperature, 850-1000 mb thickness, and the boundary layer potential temperature forecasts were commonly chosen predictors. The boundary layer relative humidity and the precipitable water were frequently used estimates of the moisture fields. As in the winter derivation, the observed surface temperature was a leading predictor when station observations were screened. There was one notable difference, however, between the spring and winter season equations. For the spring equations, climatic terms, particularly the cosine day of the year and the daily insolation, were important quantities at all projections. On the other hand, the importance during the winter of these terms was appreciably less. Thus, for the transitional spring season, factors that simulated the seasonal temperature trend were chosen in the regression equations.

6. DEVELOPMENT OF SUMMER EQUATIONS

The summer (June-August) max/min temperature forecast equations were developed from 6 seasons of model output (June 1973-August 1978), which consisted of approximately 500 days. Again, the procedure used and the predictors screened were the same as in the development of the winter and spring equations. The standard errors of estimate on the dependent sample are given in Fig. 4 for the summer equations. Note that the max is difficult to predict in this season. As we have indicated before (Hammons et al., 1976), the max is more variable than the min during the summer because of increased convective activity. The numerical models, of course, are generally unable to handle such mesoscale features. The standard errors for the min equations were small and increased very little with time because the min in the summer tends to be persistent from one day to the next. The use of observations as predictors improved the standard error by approximately 0.3°F and 0.1°F for the first and second projections, respectively.

The five most important predictors for the 0000 and 1200 GMT Alaskan summer season max/min forecast equations are given in Tables 11 and 12, respectively. These fields were nearly identical to those used for the winter and spring seasons. In all projections, the boundary layer potential temperature forecast was a significant predictor for both the max and min. When surface observations were included as potential predictors, the latest surface temperature was important in forecasting the max while both the previous min and the latest surface temperature were used for predicting the min. Evidently, the temperature regime is rather persistent in Alaska during the summer. Finally, the sine twice day of the year and the precipitable water were extremely important predictors of the min. In fact, the sine twice day of the year was used as a predictor much more frequently in the summer than in either the winter or spring seasons.

7. DEVELOPMENT OF FALL EQUATIONS

The fall (September-November) max/min temperature forecast equations were developed from 5 seasons of model output (September 1973-November 1977), consisting of approximately 400 days. Otherwise, the developmental procedure was identical to that employed for the other seasons. The standard errors of estimate on the dependent sample are given in Fig. 5. The shape and relative positions of the max and min curves are nearly identical to the analagous curves for the spring season (Fig. 3).

As in the winter and spring seasons, the min is more difficult to predict than the max. Note that the average improvement in the standard errors from the use of surface observations as predictors was approximately 0.7°F and 0.4°F for the first and second projections, respectively. This increase in accuracy exceeded that obtained for the spring season, and, in fact, approached the corresponding improvement of the winter season equations.

The five most important predictors for the 0000 and 1200 GMT Alaskan fall season max/min forecast equations are given in Tables 13 and 14, respectively. As in the spring season, the boundary layer potential temperature, relative humidity, and wind forecasts were significant predictors in forecasting the max and the min. In the fall season, however, the cosine day of the year was the most frequently used predictor in nearly all projections for both cycles and both the max and the min. Apparently, the seasonal temperature trend is an important factor in the fall season max/min forecast equations.

8. OPERATIONAL DETAILS

The MOS Alaskan max/min temperature forecasts are produced twice daily from the 7-layer PE model (National Weather Service, 1977). Model forecasts are interpolated from grid point values (via a biquadratic scheme) to the station of interest and are then used in the appropriate equation. The resulting temperature forecasts are included as part of the FMAK1 teletypewriter message available through the Kansas City Switch. The guidance is usually available around 0730 and 2100 GMT each day. More details on the other forecast elements found in the FMAK1 message may be found in Technical Procedures Bulletin No. 262 (National Weather Service, 1979).

9. CONCLUSIONS

We have derived 3-month winter, spring, summer, and fall max/min forecast equations for Alaska. Tests on independent data indicate that the forecasts produced by 3-month equations are more accurate than those produced by the older 6-month equations. It is not possible to determine from these experiments whether the new predictors or the shorter seasons are responsible for the improved accuracy. However, based on our experience, we believe that the latter factor is the primary cause. In addition, for the 60-h min from 0000 GMT, we demonstrated that the 60-h PE model fields decrease the forecast error. The MOS guidance shows skill at all projections compared to forecasts based on climatology, persistence, or a combination of these two factors. The 3-month equations became operational in March 1979.

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Table 1. Stations in Alaska for which max/min temperature forecast equations were derived.

Anchorage	ANC	Juneau	JNU
Annette	ANN	King Salmon	AKN
Barrow	BRW	Kotzebue	OTZ
Barter	BTI	McGrath	MCG
Bethel	BET	Nome	OME
Cold Bay	CDB	St. Paul Island	SNP
Fairbanks	FAI	Yakutat	YAK

Table 2. Coarse mesh primitive equation model fields used as potential predictors in developing 0000 GMT equations for Alaska to predict today's max, tomorrow's min and tomorrow's max. These forecasts are valid approximately 24, 36, and 48 hours, respectively, after 0000 GMT. As shown, the model fields are valid at various projections (hours) after 0000 GMT. One star (*) indicates that the data were smoothed by a five-point filter; two stars (**) denote a nine-point filter.

Model Field	Projection		
	Today's Max	Tomorrow's Min	Tomorrow's Max
1000-mb height	12*,24*	24*,36*	36*,48*
850-mb height	12,24	24,36	36,48
500-mb height	12,24	24,36	36,48
500-1000 mb thickness	12,24	24,36	36,48
850-1000 mb thickness	12,24	24,36	36,48
500-850 mb thickness	12,24	24,36	36,48
1000-mb temperature	12,24,24*,36*	24*,36,36*,48*	36*,48,48*,48**
850-mb temperature	12,24,24*,36*	24*,36,36*,48*	36*,48,48*,48**
700-mb temperature	12,24	24,36	36,48
Bndry layer pot temp	12,24,24*,36*	24*,36*,48*	36*,48*,48**
Bndry layer u wind	12,24*	24*,36*	36*,48*
Bndry layer v wind	12,24*	24*,36*	36*,48*
Bndry layer wnd speed	24*	36*	48*
850-mb u wind	24	36	48
850-mb v wind	24	36	48
700-mb u wind	24	24*	24**
700-mb v wind	24	24*	24**
850-mb rel vort	24*	36*	48*
500-mb geos rel vort	24*	36*	48*
850-mb vert vel	24*	36*	48*
650-mb vert vel	24*	36*	48*
Stability (700 mb-1000 mb temp)	24	36	48
Stability (500 mb-850 mb temp)	24	36	48
Mean rel hum (1000-490 mb)	12*,24*,36*	24*,36*,48*	36*,48*,48**
Precipitable water	12*,24*	24*,36*	36*,48*
Bndry layer wnd div	24*	36*	48*
Bndry layer vert vel	24*	36*	48*
850-mb temp advection	12*,24*	24*,36*	36*,48*
500-mb geo vort advec	24*	36*	48*
Bndry layer rel hum	12*,24*,36*	24*,36*,48*	36*,48*,48**
Layer 1 rel hum (1000-720 mb)	12*,24*,36*	24*,36*,48*	36*,48*,48**
Layer 2 rel hum (720-490 mb)	12*,24*,36*	24*,36*,48*	36*,48*,48**
Bndry layer mois div	24*	36*	48*

Table 3. Same as Table 2 except for equations to predict the day after tomorrow's min and the day after tomorrow's max. These forecasts are valid approximately 60 and 72 hours, respectively, after 0000 GMT. For the 60-h min, the column labelled "extnd" was actually used in the derivation of the 0000 GMT equations. The alternate set of predictors for the day after tomorrow's min (labelled "altrn") was used as an experimental set and for the development of the 60-h max from 1200 GMT data.

Model Field	Projection		
	Day after Tomrw's Min (extnd)	Day after Tomrw's Min (altrn)	Day after Tomrw's Max
1000-mb height	48*,60*	48*,48**	60*,72**,84**
850-mb height	48,60	48,48*	60,72*,84*
500-mb height	48,60	36*,48,48*	60,72*,84*
500-1000 mb thickness	48,60	48,48*	60,72*,84*
850-1000 mb thickness	48,60	48,48*	60,72*,84*
500-850 mb thickness	48,60	48,48*	60,72*,84*
1000-mb temperature	48*,60*	48*,48**	60*,72**,84**
850-mb temperature	48*,60*	48*,48**	60*,72**,84**
700-mb temperature	48*,60*	48*,48**	60*,72**,84**
Bndry layer pot temp	48*,60*	48*,48**	60*,72**,84**
Bndry layer u wind	48*,60*	48*,48**	60*,72**,84**
Bndry layer v wind	48*,60*	48*,48**	60*,72**,84**
Bndry layer wnd speed	60*	48*,48**	72*
850-mb u wind	48*,60*	48*	60*,72**,84**
850-mb v wind	48*,60*	48*	60*,72**,84**
850-mb rel vort	60**	48**	72**
500-mb geos rel vort	60**	48**	72**
850-mb vert vel	60**	48**	72**
650-mb vert vel	60**	48**	72**
Stability (700-1000 mb temp)	48*,60*	48*	60*,72**,84**
Stability (500-850 mb temp)	48*,60*	48*	60*,72**,84**
Mean rel hum (1000-490 mb)	48**,60**	48*,48**	60**,72**,84**
Precipitable water	48**,60**	48*,48**	60**,72**,84**
Bndry layer wind div	48**,60**	48**	60**,72**,84**
Bndry layer vert vel	60**	48**	72**
850-mb temp advection	48**,60**	48**	60**,72**,84**
500-mb geo vort advec	48**,60**	48**	60**,72**,84**
Bndry layer rel hum	48**,60**	48*,48**	60**,72**,84**
Layer 1 rel hum (1000-720 mb)	48**,60**	48*,48**	60**,72**,84**
Layer 2 rel hum (720-490 mb)	48**,60**	48*,48**	60**,72**,84**
Bndry layer mois div	60**	48*,48**	72**

Table 4. Other predictors used in the development of the 0000 GMT equations for Alaska. The projections for the temperature forecasts denote the approximate verification time. Hours of the observations refer to time after 0000 GMT. The same set of predictors was used to derive the 1200 GMT equations except that the current day's min was used as a potential predictor for the forecast of tomorrow's min and the previous day's max was screened as a predictor for tomorrow's max. The projections then refer to hours after 1200 GMT.

Quantity	Projection				
	24 Hr Max	36 Hr Min	48 Hr Max	60 Hr Min	72 Hr Max
Observations					
Ceiling (binary: cutoff of 5000 feet)	6	6	-	-	-
Sky cover	6	6	-	-	-
U wind	6	6	-	-	-
V wind	6	6	-	-	-
Wind speed	6	6	-	-	-
Temp	6	6	-	-	-
Dew point	6	6	-	-	-
Prev day's max	6	-	-	-	-
Prev day's min	-	6	-	-	-
Climatic Terms					
Cosine day of yr	0	0	0	0	0
Cosine twice day of yr	0	0	0	0	0
Sine day of yr	0	0	0	0	0
Sine twice day of yr	0	0	0	0	0
Daily solar insolation (top of atmosphere)	0	0	0	0	0

Table 5. Standard error of estimate (^{o}F) averaged for 14 stations in Alaska. These errors are for 0000 GMT winter equations derived from 5 years of data (December 1972-February 1977). The MOS equations use the predictors of Tables 2, 3, and 4. The climatology equations use only climatic terms; the persistence-climatology equations use climatic terms and either the previous day's max or min observation, depending on the predictand. An approximation of the valid time for the calendar day projection is also included in parentheses.

Equation Type	Projection				
	Today's Max (24-h)	Tomorrow's Min (36-h)	Tomorrow's Max (48-h)	Day after Tomorrow's Min (60-h)	Day after Tomorrow's Max (72-h)
3-month MOS	4.8 (with obs)	7.4 (with obs)	7.1	9.4 (extnd)	8.4
	5.8 (no obs)	7.8 (no obs)		9.4 (altrn)	
Climatology	13.4	14.6	13.5	14.6	13.5
Persistence-climatology	7.2	11.1	10.0	12.4	11.3

Table 6. Leading predictors for the 0000 GMT winter equations for Alaska. The ranking is based on the frequency of selection and the order in which the predictor was picked for the equation by the screening process. If a predictor was chosen first, it was assigned 10 points; if second, nine points; and so forth until the 10th predictor was given a score of one point. All model fields were taken from the coarse mesh primitive equation model.

Today's Max (with obs)	Today's Max (no obs)	Tomorrow's Min (with obs)	Tomorrow's Min (no obs)
Obs surface temp	Bndry layer rel hum	850-1000 mb thickness	Bndry layer rel hum
Bndry layer wind speed	850-1000 mb thickness	Obs surface temp	850-1000 mb thickness
Obs prev day's max	Bndry layer wind speed	Bndry layer rel hum	850-mb temperature
Bndry layer rel hum	Bndry layer pot temp	Bndry layer wind speed	Bndry layer wind speed
Precipitable water	850-mb temperature	850-mb temperature	Precipitable water

Tomorrow's Max	Day after Tomorrow's Min	Day after Tomorrow's Max
Bndry layer pot temp	Bndry layer rel hum	Bndry layer rel hum
Bndry layer rel hum	850-mb v wind	Bndry layer pot temp
Bndry layer wind speed	850-1000 mb thickness	850-1000 mb thickness
850-1000 mb thickness	850-mb temperature	850-mb v wind
500-mb height	Precipitable water	850-mb temp advection

Table 7. Same as Table 6 except for 1200 GMT winter equations.

Tomorrow's Min (with obs)	Tomorrow's Min (no obs)	Tomorrow's Max (with obs)
Obs minimum temp	Bndry layer rel hum	850-1000 mb thickness
850-mb temperature	850-1000 mb thickness	Obs surface temp
Bndry layer rel hum	Bndry layer wind speed	850-mb temperature
Bndry layer wind speed	850-mb temperature	Bndry layer pot temp
Precipitable water	Precipitable water	Bndry layer wind speed
Tomorrow's Max (no obs)	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**
850-1000 mb thickness	Bndry layer rel hum	Bndry layer pot temp
Bndry layer rel hum	Bndry layer pot temp	Bndry layer rel hum
Bndry layer pot temp	850-1000 mb thickness	Bndry layer wind speed
Bndry layer wind speed	Bndry layer wind speed	850-1000 mb thickness
850-mb temperature	Precipitable water	850-mb v wind

Table 8. Equation to predict today's max (°F) at Fairbanks, Alaska from 0000 GMT model data. Development of this winter season (December-February) equation was based on 6 years, or approximately 500 days, of data (1972-78). A star (*) indicates the field was smoothed by a five-point filter.

Predictor	Regression Coefficient	Cumulative Reduction of Variance (%)
0600 GMT observed surface temp (°F)	.380	77.8
24-hr PE 500-1000 mb thickness (m)	.021	83.1
Daily insolation (watts/m^2)	.122	85.3
24-hr PE bndry layer wind speed* (m/s)	1.046	86.7
24-hr PE bndry layer pot temp* (K)	1.097	87.4
Previous day's maximum (°F)	.236	87.9
24-hr PE bndry layer rel hum* (%)	.171	88.1
12-hr PE layer 1 rel hum* (%)	-.075	88.3
12-hr PE bndry layer pot temp (K)	-.588	88.5
24-hr PE 850-mb temp advec* (K/s x 10^{-5})	-.224	88.7
Initial constant = -263.1°F	Standard error of estimate = 6.61°F	

Table 9. Same as Table 6 except for the Alaskan 0000 GMT spring equations.

Today's Max (with obs)	Today's Max (no obs)	Tomorrow's Min (with obs)	Tomorrow's Min (no obs)
Obs surface temp	850-1000 mb thickness	Obs surface temp	850-mb temperature
Bndry layer pot temp	Bndry layer pot temp	850-mb temperature	Cosine day of year
850-mb temperature	Cosine day of year	Precipitable water	Bndry layer rel hum
Cosine day of year	Bndry layer rel hum	Bndry layer rel hum	Daily insolation
Obs prev day's max	Precipitable water	Sine twice day of year	Bndry layer pot temp
Tomorrow's Max	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**	
Bndry layer pot temp	850-mb temperature	850-1000 mb thickness	
Cosine day of year	Cosine day of year	Cosine day of year	
850-mb temperature	Daily insolation	Bndry layer pot temp	
850-1000 mb thickness	850-1000 mb thickness	Daily insolation	
Daily insolation	Bndry layer rel hum	Precipitable water	

Table 10. Same as Table 6 except for the Alaskan 1200 GMT spring equations.

Tomorrow's Min (with obs)	Tomorrow's Min (no obs)	Tomorrow's Max (with obs)
Obs minimum temp	850-mb temperature	Obs surface temperature
850-mb temperature	Bndry layer rel hum	850-mb temperature
Bndry layer rel hum	850-1000 mb thickness	850-1000 mb thickness
Daily insolation	Bndry layer pot temp	Cosine day of year
Bndry layer wind speed	Cosine day of year	Bndry layer u wind
Tomorrow's Max (no obs)	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**
850-1000 mb thickness	850-mb temperature	850-1000 mb thickness
850-mb temperature	Bndry layer rel hum	Cosine day of year
Cosine day of year	Cosine day of year	Bndry layer u wind
Bndry layer rel hum	Daily insolation	850-mb temperature
Precipitable water	Bndry layer pot temp	500-mb height

Table 11. Same as Table 6 except for the Alaskan 0000 GMT summer equations.

Today's Max (with obs)	Today's Max (no obs)	Tomorrow's Min (with obs)	Tomorrow's Min (no obs)
Obs surface temp	Bndry layer pot temp	Obs prev day's min	Sine twice day of year
Bndry layer pot temp	850-1000 mb thickness	Precipitable water	Bndry layer pot temp
Bndry layer v wind	850-mb rel vort	Obs surface temp	Layer 1 rel hum
850-mb temperature	Sine twice day of year	Sine twice day of year	Precipitable water
Bndry layer u wind	Bndry layer v wind	Bndry layer pot temp	Cosine day of year
Tomorrow's Max	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**	
Bndry layer pot temp	Sine twice day of year	850-mb u wind	
850-mb temperature	Precipitable water	850-1000 mb thickness	
Sine twice day of year	Cosine day of year	Sine twice day of year	
Bndry layer v wind	Bndry layer pot temp	850-mb v wind	
1000-mb temperature	850-mb u wind	Cosine twice day of year	

Table 12. Same as Table 6 except for the Alaskan 1200 GMT summer equations.

Tomorrow's Min (with obs)	Tomorrow's Min (no obs)	Tomorrow's Max (with obs)
Obs minimum temp	Sine twice day of year	Obs surface temp
Precipitable water	Precipitable water	850-mb temperature
Bndry layer pot temp	Bndry layer pot temp	Bndry layer v wind
Sine twice day of year	Cosine day of year	Bndry layer pot temp
Obs surface temp	Layer 1 rel hum	700-mb u wind
Tomorrow's Max (no obs)	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**
850-mb temperature	Sine twice day of year	Sine twice day of year
700-mb u wind	Precipitable water	850-mb u wind
Bndry layer pot temp	Bndry layer pot temp	850-mb temperature
Sine twice day of year	Cosine day of year	Bndry layer pot temp
Bndry layer v wind	850-mb temperature	850-1000 mb thickness

Table 13. Same as Table 6 except for the Alaskan 0000 GMT fall equations.

Today's Max (with obs)	Today's Max (no obs)	Tomorrow's Min (with obs)	Tomorrow's Min (no obs)
Obs surface temp	Cosine day of year	Obs surface temp	Cosine day of year
Obs prev day's max	Bndry layer rel hum	Bndry layer rel hum	Bndry layer rel hum
Bndry layer pot temp	Bndry layer pot temp	850-mb temperature	850-mb temperature
Cosine day of year	850-1000 mb thickness	Cosine day of year	Bndry layer pot temp
Bndry layer wnd speed	Bndry layer wnd speed	Bndry layer wnd speed	Bndry layer wnd speed
Tomorrow's Max	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**	
Cosine day of year	Cosine day of year	Cosine day of year	
Bndry layer pot temp	Bndry layer rel hum	850-1000 mb thickness	
Bndry layer rel hum	850-1000 mb thickness	Bndry layer pot temp	
850-1000 mb thickness	850-mb temperature	Bndry layer rel hum	
Bndry layer wnd speed	850-mb temp advection	Precipitable water	

Table 14. Same as Table 6 except for the Alaskan 1200 GMT fall equations.

Tomorrow's Min (with obs)	Tomorrow's Min (no obs)	Tomorrow's Max (with obs)
Obs minimum temp	Cosine day of year	Cosine day of year
850-mb temperature	850-mb temperature	Obs surface temperature
Cosine day of year	Bndry layer rel hum	Bndry layer pot temp
Bndry layer wnd speed	Bndry layer wnd speed	Obs prev day's max
Mean rel hum	850-1000 mb thickness	850-1000 mb thickness
Tomorrow's Max (no obs)	**Day after Tomorrow's Min**	**Day after Tomorrow's Max**
Cosine day of year	Cosine day of year	Cosine day of year
Bndry layer pot temp	850-mb temperature	Bndry layer pot temp
Bndry layer rel hum	Bndry layer rel hum	Bndry layer rel hum
850-1000 mb thickness	Bndry layer pot temp	Bndry layer wnd speed
Bndry layer wnd speed	Bndry layer wnd speed	850-mb temperature

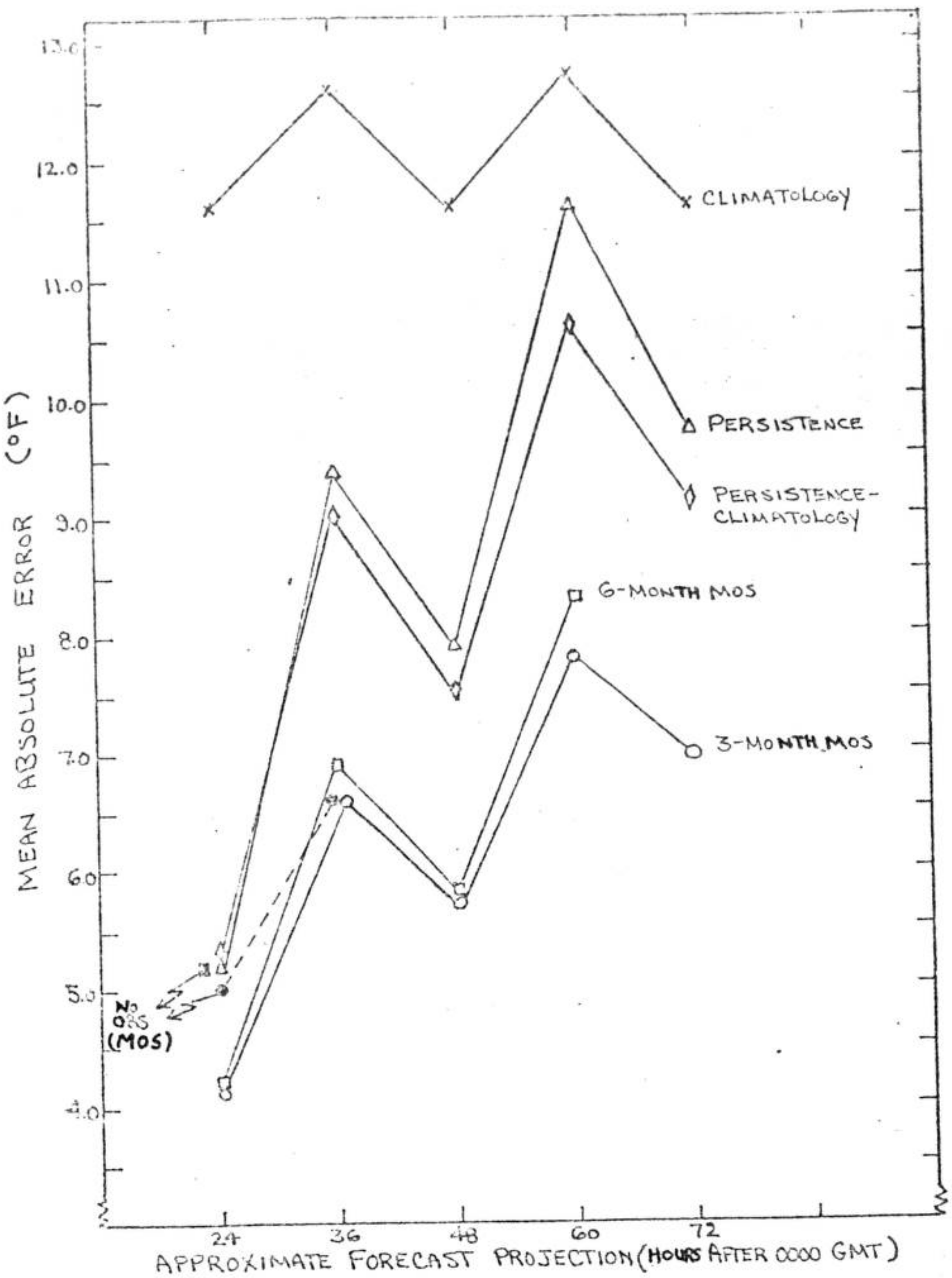

Figure 1. Average mean absolute errors (°F) of test forecasts made at 14 stations in Alaska for the 1977-78 winter season. All forecasts were produced from 0000 GMT data. The circle (**O**) represents guidance based on new 3-month season MOS equations; the rectangle (**□**) represents the forecasts from the older 6-month season equations. The diamond (**◊**) indicates forecasts based on a combination of persistence and climatology, while the triangle (**△**) denotes guidance due to persistence only. Finally, the X indicates guidance produced from regression equations dependent only on climatic terms. For the first two projections, MOS forecasts based on equations that do not use surface observations as predictors are denoted by darkened figures.

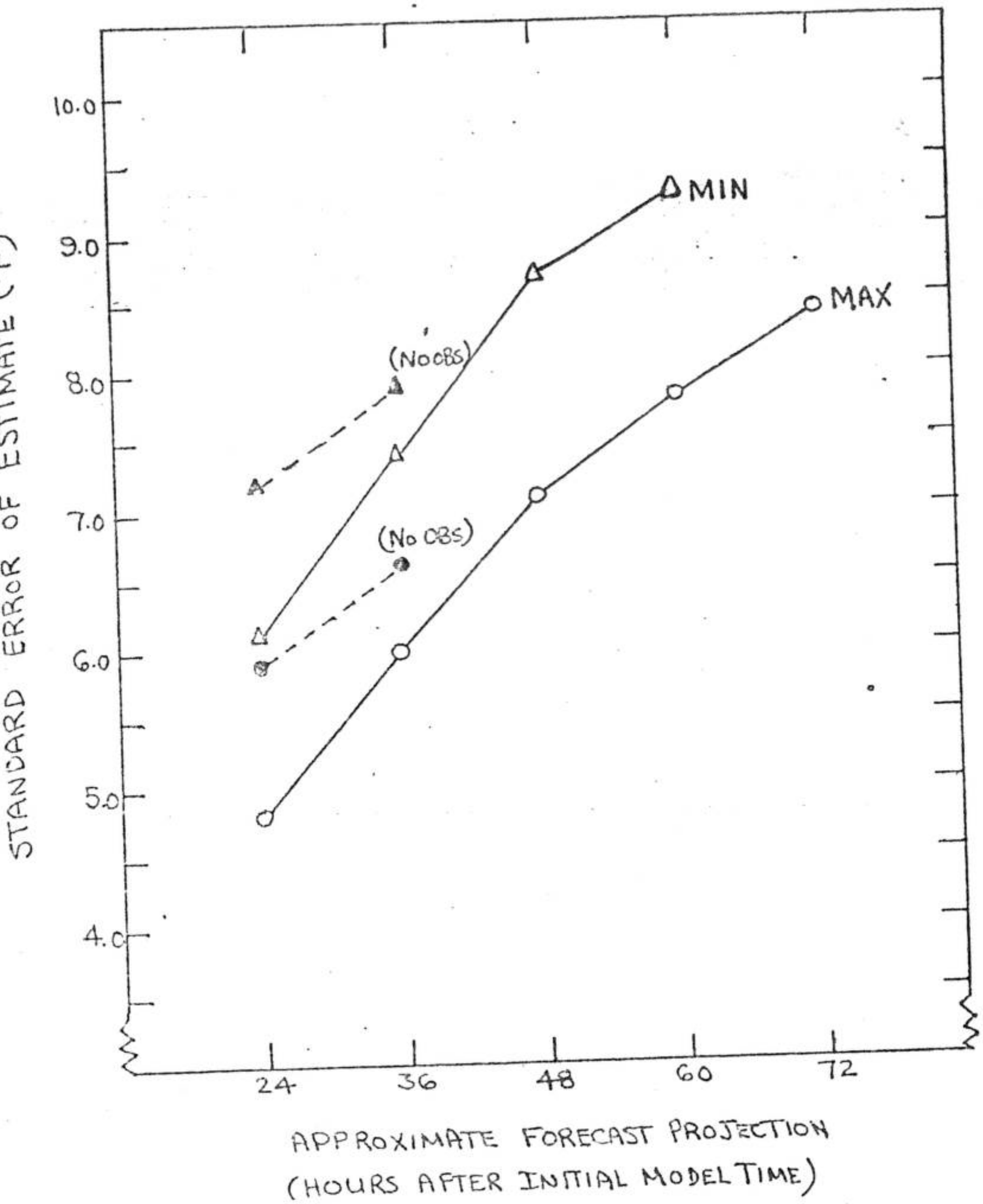

Figure 2. Standard errors of estimate averaged at 14 stations in Alaska for the winter 3-month equations. For both the max and min, errors are given as a function of the approximate projection in hours after the initial model time. The hollow circles represent standard errors for the max forecast equations; the hollow triangles, for the min forecast equations. For the first two projections, the darkened figures denote standard errors for the backup equations which do not use surface observations as predictors.

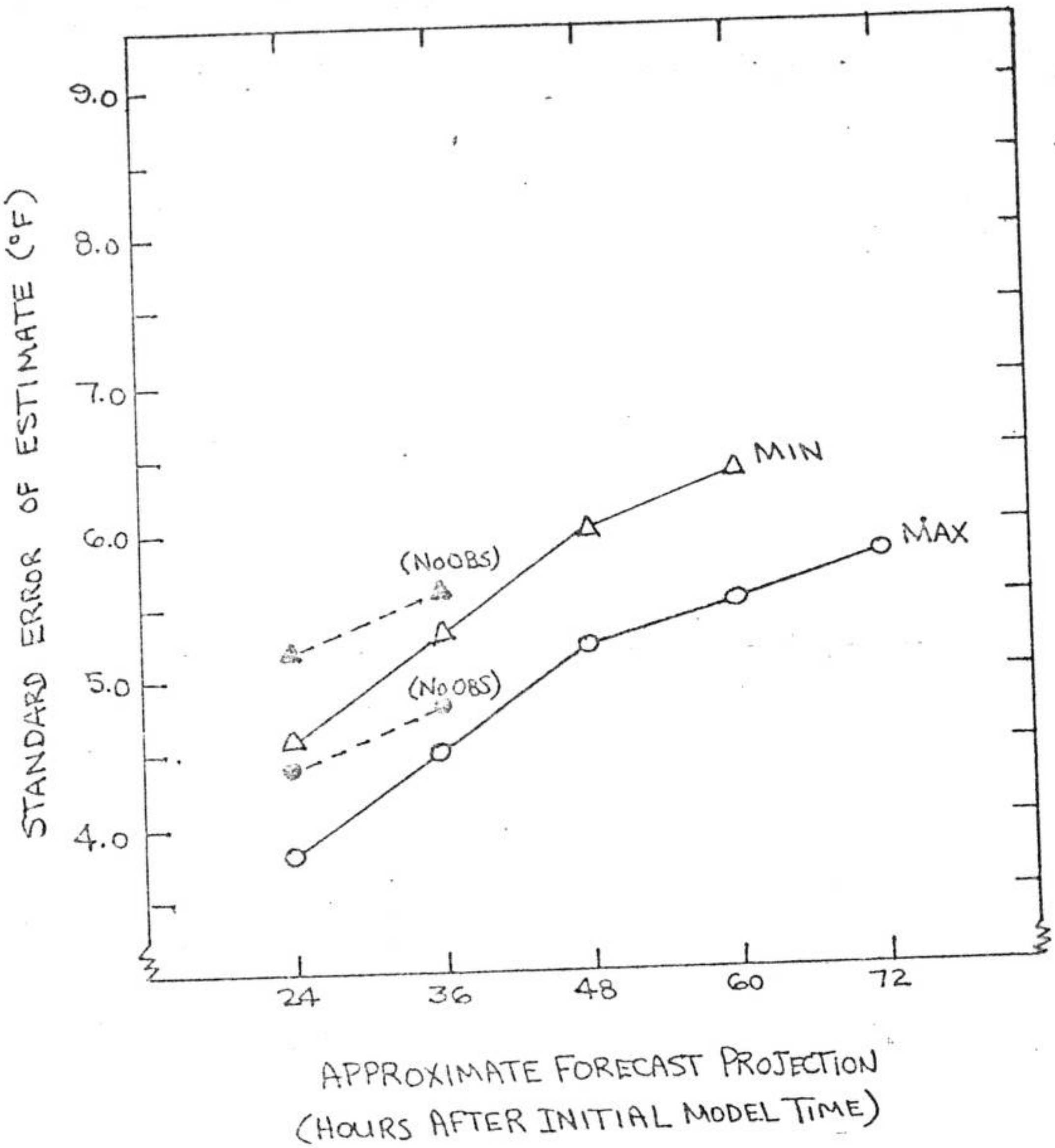

Figure 3. Same as Fig. 2 except for the spring equations.

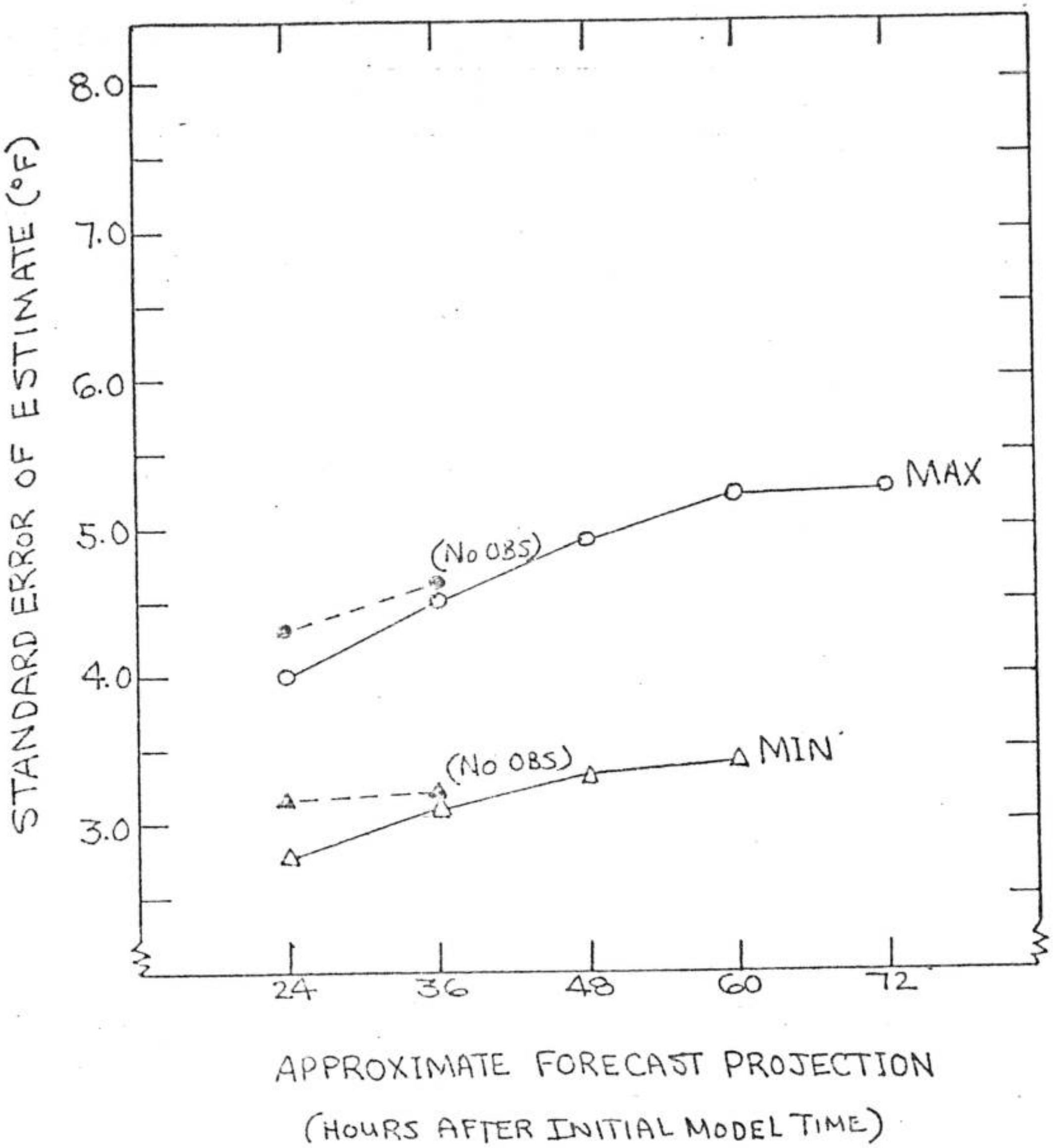

Figure 4. Same as Fig. 2 except for the summer equations.

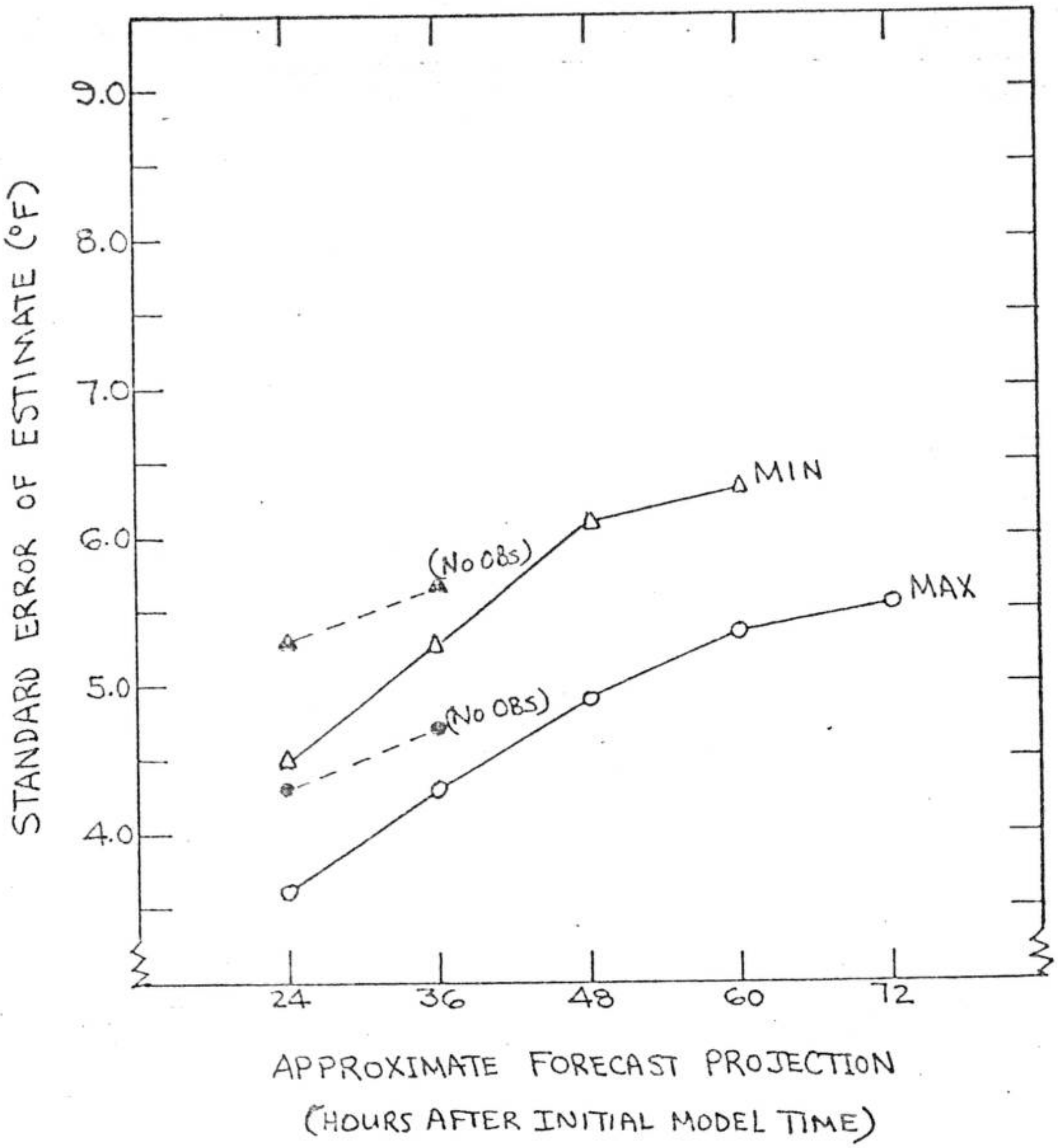

Figure 5. Same as Fig. 2 except for the fall equations.